The Cost of Spectrum Auction Distortions

Review of spectrum auction policies and economic assessment of the impact of inefficient outcomes

October 2014

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Stefan Zehle, MBA
CEO,
Coleago Consulting Ltd
Tel: +44 7974 356 258
stefan.zehle@coleago.com

Nick Fookes
Managing Consultant,
Coleago Consulting Lt
Tel: +44 7710 350 816
nick.fookes@coleago.com

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1. Executive Summary

1.1 Objectives and scope of this study

Coleago Consulting was invited by the GSMA to examine the influence of policy choices on the outcome of mobile spectrum auctions, and to address the following questions in particular:

1. **In the context of an auction, which secondary policy choices are most liable to distort the spectrum allocation process?**
2. **To what extent can mobile operators reasonably mitigate these distortions (for example, by adjusting their auction bid-values)?**
3. **What are the downstream consequences for consumers and the wider economy of these distortions?**
4. **How can policy-makers reduce the risk of adverse results in the auction and of adverse downstream consequences?**

Based on an international review of past auctions, this report highlights avoidable risks of policy failure and seeks to promote the adoption of best practices in future spectrum awards. The next sections summarise our key findings.

1.2 Policies that influence spectrum auction outcomes

Many areas of regulatory policy have a bearing on spectrum auction results and thus on market outcomes, however those aspects that present a higher risk of adverse consequences deserve special attention. These are summarised in the table below, with our assessment of their potential severity and of the scope for operators to mitigate distortions by using reasonable corrective strategies.

EXHIBIT 1: OVERVIEW OF THE MAIN RISKS OF DISTORTION

Category	Policy choice	Key risks	Potential severity	Scope to mitigate
Available spectrum and competition safeguards	**Explicit or de facto spectrum reservations (set-asides)**	Unsold spectrum	High	Low
		Spectrum is secured by inefficient users	High	Low
		Spectrum costs are driven up for incumbents (due to artificial scarcity)	High	Low
	Inefficient lot sizes	Spectrum fragmentation	High	Medium*
	Use of specific lots only	Technical inefficiency due to fragmented assignment	Medium	Medium*
	Inclusion of expiring licences in auction	Risk to business continuity	High	Low*
		Risk of predatory bidding	Medium	Medium
Reserve prices and licence payment terms	**Artificially high reserve prices**	Unsold spectrum	High	Low
		Unduly high costs for operators with risk of adverse downstream consequences	High	Low
Choice of auction format	**First-price sealed-bid auction**	Potentially excludes efficient operators	High	Low
		Winners' curse (Operators pay significantly more than required to win)	High	Low
		Knock-out risk (due to operators paying less than own valuation to mitigate winners' curse)	High	Low
		Price disparities between similar spectrum in the same market	Medium	Low
		Inefficient allocations when bidders have fixed budget constraints	High	Low
Licence terms and regulatory landscape	**Technological restrictions**	Unsold spectrum	High	Low
		Inefficient deployment	High	Low
	Regulatory uncertainty (e.g. uncertain future licence renewal terms)	Spectrum misallocation	High	Low
		Unsold spectrum	Medium	Low

These policies are assessed in greater detail in section 3, using actual examples from past mobile spectrum auctions, where available, to illustrate the associated risks.
Our view is that there are two overriding (and party overlapping) public interest concerns. First, that scarce resources should be put to the most productive use, and secondly, that mobile services of sufficiently high quality and reach should be available to consumers at sustainably low prices. Inefficient spectrum allocations, unduly high spectrum fees and diminished competition pose the main threats in this regard:

- **Inefficient spectrum allocations may lead to a reduction in total industry capacity, potentially leading to greater network congestion and/or higher industry costs;**
- **High spectrum fees might be passed on to consumers in the form of higher retail prices and/or reduced investment in infrastructure and services (due for example to a collective retrenchment under to budgetary pressures);**
- **Diminished competition may lead to higher retail prices as well as reduced investment and innovation, thus impairing national sector performance.**

Likely consequences include reduced adoption and consumption of mobile services, bearing negatively on national digital inclusion and economic productivity[1].

Policy measures that might attenuate some of the risks highlighted in this report and thus promote the public good include the following:

- **Applying spectrum floors in the event spectrum-in-use is being re-auctioned, to minimise the threat to business continuity[2];**
- **Aligning reserve prices with the higher of (a) the costs of freeing up the spectrum for mobile use or (b) the valuations based on alternative industry uses, to avoid imposing unduly high costs on the industry (that might otherwise be passed on to consumers in the form of higher retail prices or reduced investment and innovation);**
- **Providing deferred licence fee payment terms to equalise the opportunity for operators to secure the resources they need to pay for spectrum, in light of possible differences in their ability to raise substantial funds in advance;**
- **Modifying auction rules to minimise the scope for predatory bidding strategies designed to drive higher costs for rival bidders;**
- **Imposing 'use it or lose it' provisions in the form of non-band specific coverage obligations to minimise the threat of spectrum hoarding, particularly where spectrum is awarded at a discount to entrants via a set-aside; for example, band-agnostic coverage obligations would minimise the risk that entrants secure spectrum with the aim to hold and sell at a premium;**
- **Ensuring early industry participation when preparing/deciding on spectrum award procedures and ensuring adequate transparency level for all auction participants throughout;**
- **Avoiding the use of auctions when an obvious distribution of available resources among operators can be readily identified, to minimise the risk of perverse outcomes.**

1 The positive influence of mobile (and mobile broadband) adoption is well documented. See for example 'Mobile Telephony - A Transformational Tool for Growth and Development', 2009, Christine Zhen-Wei Qiang, Proparco's Magazine (available here), and Waverman, Meshi and Fuss, 'The Impact of Telecoms on Economic Growth in Developing Countries', in The Vodafone Policy Paper Series, Number 2, March 2005, available on the World Bank website.

2 A spectrum floor is the inverse of a spectrum cap: it ensures that an operator is guaranteed a minimum viable portfolio, provided it is willing to pay the reserve price.

1.3 Economic cost of inefficient spectrum allocations

While the adverse consequences of high spectrum fees and impaired competition are perhaps best dealt with on a qualitative basis, the economic cost of inefficient spectrum allocations can readily be quantified, by analysing their effect on total industry capacity. Comparing the latter with potential (i.e. unconstrained) demand allows us to express the inefficiency in terms of foregone consumption. As described in section 4.3, this can in turn be used to gauge the impact on Consumer and Producer Surplus (CS and PS).

We examined three cases in particular, the results of which are summarised in the table below.

EXHIBIT 2: ECONOMIC IMPACT ASSESSMENT CASE STUDIES

Case study	Outcome	Estimated economic impact
India 850MHz and 1800MHz awards (2012-2014)	15% of the available 850MHz plus 1800MHz bandwidth is unutilised	CS plus PS foregone: $3.6bn p.a.
Bangladesh 3G auction (2013)	37.5% of the spectrum on offer was unsold	Potential GDP growth impact: $1.0bn p.a.
Chile AWS auction (2009)	43% of industry bandwidth was reserved for entrants, serving 0.9% of the market five years on	GDP growth foregone: $0.4 -$3.4bn p.a.

Source: Coleago Consulting
Note: CS and PS refer to Consumer and Producer Surplus

The social and economic cost of inefficient allocations is often substantial, especially if spectrum is left fallow or is underutilised for prolonged periods. Where spectrum is left unsold due to a high reserves, these costs sometimes far exceed the extra auction proceeds that may reasonably be attributed to them, as was the case in India in particular (see section 4.5.1).

1.4 Auction Distortion Report

To highlight the impact of policy choices in practice, we examined six completed spectrum awards in greater detail (see section 5). The main policy aspects considered in each case are summarised in the table below.

EXHIBIT 3: SAMPLE AUCTIONS

Award	Main policy issues examined
India 850 and 1800MHz (2012-2014)	High reserve prices, technology bias, regulatory uncertainty, historic spectrum fragmentation
Australia 700MHz (2013)	High reserve prices
Chile AWS (2009)	De facto spectrum set-aside for entrants
Chile 700MHz (2014)	Spectrum packaging and award process
Canada AWS (2008)	Spectrum set-aside for entrants
Bangladesh 3G (2013)	High reserve prices

Source: Coleago Consulting

On the basis of the outcomes, we attributed a high risk of distortion to the overall award process in all cases except the 700MHz award in Chile. We consider that the pragmatic packaging of licences, low reserve prices and overall focus on public interest criteria delivered a positive result, in contrast with the other examples in our sample.

1.5 Key conclusions

Our analysis leads us to conclude the following:

1. **Explicit or de facto spectrum set-asides present a high risk of distortion and inefficiency. In an era of mobile network consolidation, diverting spectrum to new, infrastructure-based entrants seems a highly questionable policy.**
2. **Governments in many countries appear to view spectrum policy as an instrument to finance the state. However, measures designed to maximise licence fee receipts risk introducing downstream inefficiencies that cause net social and economic harm.**
3. **The overriding focus of spectrum policy should be to promote: (a) efficient use of spectrum resources, particularly where internationally harmonized; (b) network investment and innovation; (c) undistorted competition; and (d) sustainably high output and low retail prices.**

2. Introduction

2.1 Context, objectives and scope

The use of auctions to determine the allocation and pricing of mobile radio-spectrum licences is now common practice in both emerging and developed countries. In contrast with administered processes such as 'beauty contests', auctions offer an objective award mechanism, which diminishes the scope to contest the outcome. Auctions may also promote economic efficiency by distributing scarce resources to those who value these the most, and who might thus be expected to put them to the most productive use. Finally, when there is intense competition for spectrum on offer, auctions may generate higher licence rents for the treasury, which, it is often argued, yield further social gains[3].

While auctions ostensibly take the question of winner and price determination out of the hands of public officials, the impact of secondary policy choices on outcomes should not be underestimated. This report examines the extent to which regulatory and spectrum-award policies are liable to produce adverse (if usually unintended) results, taking account of the scope for operators to mitigate distortions by pursuing reasonable corrective strategies. Regulatory measures that reduce the risk of inefficient outcomes are also considered.

This report contains the following in particular:

1. **A review of relevant policy measures, in light of international precedents;**
2. **An assessment of the social and economic impact of downstream inefficiencies, including a quantitative assessment for three specific cases;**
3. **A detailed review of six completed spectrum-awards, focusing on the risk of distortion introduced by specific policy measures.**

Our main objective is to highlight avoidable risks of policy failure and to advocate the adoption of best practices in future spectrum awards.

2.2 Public interest considerations

Our view is that the public good is generally best served by policies that advance the following objectives:

- **Efficient allocation: a distribution of spectrum that maximises social utility;**
- **Transparency of the award process;**
- **Increased broadband access including for rural and remote customers;**
- **Innovation and network investment;**
- **Undistorted competition;**
- **A high net economic return to the public.**

It is hard to argue against any of these criteria. Inefficient spectrum allocations for example, may lead to a reduction in total industry capacity, potentially leading to greater network congestion. Nor could one reasonably wish for an opaque allocation process, slow or curtailed network deployment and reduced consumer choice.

However, there is ample scope to disagree on the meaning of the last point –i.e. what constitutes a high net return to the public. Policy makers often seem to emphasise direct auction proceeds to Government at the expense of wider social and economic benefits. According to Hazlett and Munoz, "economists largely evaluate [policy] measures according to their effectiveness in raising bids, ignoring retail market consequences"[4].

3 Licence receipts are widely deemed a more efficient form of state funding than general taxation, because taxes are susceptible to deadweight losses. See Thomas W. Hazlett, Roberto E. Muñoz, and Diego B. Avanzini, "What Really Matters in Spectrum Allocation Design", 2012, 10 Nw. J. Tech. & Intell. Prop. 93, (page 2).

4 Hazlett et al, 2012 (page 3).

Their main point is that the wider economic value generated by the mobile industry far outstrips direct auction revenues, and that measures that jeopardise the former in favour of the latter tend therefore to be too narrow in their focus.

Using market data in the United States between 1991 and 2008, they reached a lower-bound estimate for the 2009 Consumer Surplus in the order of $200 billion per year, or $4,000 billion in present-value terms (using a 5% discount rate). This is 80x greater than the roughly $50 billion raised by the FCC through spectrum auctions over the same period. They argue further that in order to compare efficiency gains, the social savings implied by auction receipts need to be considered rather than the pure transfers. In other words, the avoided deadweight losses that would have been incurred by using alternative means of revenue-generation should be taken as a basis. Assuming deadweight losses of 33%, the $50 billion raised by the FCC corresponds with social savings of around $17 billion. This yields a ratio of about 240x in favour of retail market efficiencies. In light of this striking result, the authors observe the following:

The Consumer Surplus in the United States is 80x greater than the $50bn raised through spectrum auctions between 1991 and 2008.

> *"This more than two order of magnitude difference puts spectrum allocation policy into sharp focus. Delicate adjustments that seek to juice auction receipts but also alter competitive forces in wireless operating markets are inherently risky. A policy that has an enormous impact in increasing license revenues need impose only tiny proportional costs in output markets to undermine its social utility. So, for example, a new auction design that (heroically) doubled auction revenues would, if it reduced consumer surplus by just one-half of one percent, produce costs in excess of benefits[5]."*

Hazlett et al are predominantly concerned with the effect of policy on the competitive landscape, and with measures designed to boost bid contention by restricting supply. Yet similar conclusions may be drawn with respect to spectrum fees alone: operators need only pass on a proportion of spectrum fees to consumers (in the form of higher retail prices[6] or reduced investment[7]) to offset the social gains attributed by certain governments to direct auction proceeds.

Higher retail prices and/or reduced network investment, whether these are caused by artificially high spectrum costs or by reduced competition, undermine the adoption and consumption of mobile services, bearing negatively on digital participation and economic productivity. Moreover, once they are lost, these economic benefits cannot be recovered.

2.3 Organisation of the report

Section 3 contains a broad review of relevant policies and the risk of distortion that they engender, illustrated with practical examples where available. The social and economic impact of inefficient spectrum allocation is assessed in section 4, while section 5 covers our 'Auction Distortion Report'. The latter examines six completed awards and assesses the risk of distortion caused by a combination of measures.

5 Ibid (page 10).

6 By higher retail prices, we mean relative to the counterfactual case. This could simply be achieved through slower price erosion.

7 If spectrum costs are excessive, budgetary constraints could potentially lead to a collective retrenchment, reducing outputs. See also J.Bauer, 'Spectrum auctions, pricing and network expansion in wireless telecommunications', 2001 (available here). Bauer argues against the theory that sunk costs (such as auction fees) have no bearing on prices and investment.

3. Policy choices that influence spectrum auction outcomes

3.1 Overview

Policy choices can have a dramatic impact on the outcomes of spectrum auctions. In the following sections, we examine the types of measures introduced by the state, their potential influence on results, and the scope for auction participants to mitigate distortions by pursuing reasonable strategies.

These measures fit broadly within five distinct categories:

- **Available spectrum lots and competition safeguards;**
- **Reserve prices and licence payment terms (including annual spectrum fees);**
- **Scheduling or timing of spectrum awards;**
- **Choice of auction format;**
- **Licence terms and regulatory landscape.**

Certain policies are prone to distort auction outcomes to a greater extent than others, although much depends on the circumstances of individual awards. Those measures which generally present the greatest threat to efficiency and consumer welfare are illustrated in more detail in the Auction Distortion Report in section 5, which covers six specific cases.

3.2 Available spectrum lots and competition safeguards

The quantity, nature and packaging of the spectrum that individual operators are able to pursue will bear significantly on auction outcomes. Relevant aspects include:

- **Spectrum set-asides, floors and/or spectrum-acquisition limits;**
- **Allocation of specific or generic lots;**
- **Lot sizes;**
- **The possible inclusion of expiring usage-rights in combined awards;**
- **Awards on a regional versus national basis.**

3.2.1 Spectrum set-asides, floors and caps

Spectrum set-asides for new entrants risk tying scarce resources to inefficient users for a prolonged period to the public detriment.

Spectrum set-asides, floors and/or spectrum-acquisition caps are typically designed to prevent excessive spectrum concentration. These need to be determined with great care to avoid unduly distorting outcomes. From a public interest perspective, the main risks include inefficient spectrum use and, in the case of spectrum reservations, potentially higher spectrum costs on aggregate, resulting in higher retail prices and/or reduced network investment. Recent examples of unfavourable outcomes caused by (de-facto) spectrum reservations are provided below.

- Spectrum acquisition caps in the Netherlands' 2.6GHz auction in 2010 were so tight as to reflect a de-facto set aside for new entrants. Since only two new entrants participated in the auction (instead of the five anticipated by the government), the entire TDD band and several blocks of FDD spectrum were unsold. However, the government was able to dispose of these lots in the subsequent multiband auction in 2012. The delay in the allocation had limited impact in this case, because sufficient LTE capacity could be provided using other bands in the near term.
- In Belgium, the packaging of lots in 2011 reflected a de-facto reservation for an entrant of 2x15MHz at 2.6GHz which was unsold. It will be more difficult to remedy this inefficiency than was the case with unsold 2.6GHz in the Netherlands, because of the current band-plan which is enshrined by Royal Decree.
- The applicable spectrum caps in Chile effectively excluded the three incumbents from the AWS auction in 2009, leading to an award of 2x45MHz to two new entrants. Over four years later, this spectrum serves less than 1% of the market. This inefficient use of spectrum is likely to be difficult to reverse. The economic impact of this inefficiency is assessed in section 4.
- The 2008 AWS spectrum auction in Canada included 2x45MHz. One 2x5MHz and two 2x10MHz blocks were available to all bidders and two 2x5MHz blocks and one 2x10MHz block had been set aside for new entrants. The auction followed an SMRA format on a regional basis. There were five significant new entrants (Shaw, Wind, Mobilicity, Videotron and Eastlink) who won spectrum. Shaw, an existing fixed operator has not deployed 5 years after the auction. Shaw plans to resell the spectrum at a premium to a large incumbent after the five year lock-up period ends in 2014. This means the benefit of the set-aside is transferred to private shareholders. Accordingly, the public lost out due to lower auction receipts. Mobilicity is in bankruptcy administration and Wind is near insolvent. Its shareholders are now seeking to exit the market. Both operators had insufficient spectrum to deploy LTE and HSPA and opted for HSPA, whereas other operators deployed LTE in the AWS band. The Government's attempt to create a fourth national carrier failed with great cost to the public.
- During the 2012 multiband auction in the Netherlands, 2x10MHz at 800MHz was set aside for the recent entrants. The net effect of this reservation was to artificially increase contention among the three incumbents (KPN, Vodafone and T-Mobile) for the remaining 2x20MHz, leading to exceptionally high spectrum prices. KPN suffered a cut in its credit rating following the auction, which is likely to hamper investment. It is perhaps too early to tell whether or not the award of a third of the prime 800MHz spectrum to a recent entrant will lead to efficient use of this spectrum resource. However, the high burden of spectrum fees on the industry is almost certain to be felt, indirectly, by consumers.

EXHIBIT 4: IMPACT OF EXPLICIT OR DE FACTO SPECTRUM SET-ASIDES

Potential impact	Examples	Severity	Scope to mitigate
Spectrum is acquired by inefficient users	Chile AWS auction (2009) Canada AWS (2008)	High High	Low Low
Spectrum remains unsold	Netherlands 2.6GHz (2010) Belgium 2.6GHz (2011)	Low Medium	Low Low
Spectrum is not deployed	Canada AWS (2008)	High	Low
Increased spectrum costs for incumbents	Netherlands 800MHz (2012)	High	Low

Source: Coleago Consulting

3.2.2 Generic versus specific lots and lot sizes

If the lots on offer reflect specific frequency ranges, there is a risk that operators secure non-contiguous holdings within a given band. This would be technically inefficient. A possible solution is to auction generic lots instead and to assign contiguous ranges during a separate process, once the quantities secured by each bidder is known. In theory however, the use of generic blocks might skew results if the position within a given band has a significant impact on values: uncertainty over the final assignment may distort bid behaviour. An approach taken in some instances (e.g. the UK multiband auction in 2013) has been to include a single specific lot in a band alongside generic lots, and applying a contiguity constraint during the assignment stage. This mitigates both the risk of technical inefficiency and of distorting the allocation process.

Where practicable, spectrum is now typically awarded in blocks of 5MHz duplex in the case of Frequency Division Duplex (FDD) spectrum or simplex in the case of Time Division Duplex (TDD). This is widely considered the minimum for suitable 3G or 4G deployment in any given band[8]. Awarding spectrum in block sizes smaller than 5 MHz may lead to reduced efficiency.

The historic auctioning of spectrum in smaller sizes in India, for example, has led to severe spectrum and technology fragmentation. In principle, operators should be able to aggregate spectrum to achieve larger, more efficient blocks, although the sale of specific rather than generic lots using an SMRA[9] hampers the pursuit of contiguous allocations. Moreover, once fragmentation arises, it is difficult to remedy.

EXHIBIT 5: IMPACT OF INEFFICIENT LOT SIZES

Potential impact	Examples	Severity	Scope to mitigate
Spectrum fragmentation	Historic awards in India	High	Medium

Source: Coleago Consulting

3.2.3 Inclusion of expiring usage rights

In some cases, the lots on offer include expiring licences alongside new mobile spectrum. For example, all existing spectrum in use was sold together with the new Digital Dividend frequencies, in 'Big Bang' combined awards in Switzerland, Ireland and the Netherlands during 2012. The Norwegian 800MHz auction that concluded in December 2013 also included expiring 900MHz and 1800MHz licences.

These auctions introduce a significant risk to business continuity, especially if the process involves a sealed-bid stage, which denies bidders the opportunity to react to unforeseen events. In the Norwegian case, incumbent Tele2 lost all of its existing 2G holdings, leaving the business crippled. Tele2 has since announced its exit from the Norwegian market, with a sale of its existing assets to rival TeliaSonera[10].

Moreover, the use of a first-price sealed bid format offered the company limited scope to manage this risk during the auction itself.

8 It may be argued that a channel width of10MHz duplex is required to achieve the performance gains of LTE in a given FDD band. However, carrier aggregation using LTE advanced may enable efficient use of a 2x5MHz block in combination with spectrum in other bands.

9 SMRA – Simultaneous Multiple Round Ascending auction.

10 Reuters, 7 July 2014.

Subject to the format of the award, “Big Bang” auctions are also vulnerable to distortions caused by the adoption of potentially predatory bidding strategies. All other things being equal, incumbents should generally reach higher valuations for their spectrum in use, because their network deployment costs will already be sunk. Yet this offers an opportunity for one operator to game the auction process by bidding aggressively for the lots of one of its competitors and thus drive up prices paid by other operators in a market. In these circumstances, operators may find themselves in a difficult position: the unwelcome choice is either to respond by over-bidding at the cost of long term higher input costs or to lose potentially vital resources. To address these issues and preserve overall efficiency, regulators might consider applying spectrum floors or use an administered process for spectrum-licence renewal.

3.2.4 Regional versus national awards

In larger countries, finally, spectrum may be awarded on a regional rather than a national basis. Regional licences are common in certain larger geographic markets notably in the US, Canada, Brazil, India and Australia. Geographic fragmentation of spectrum licences may lead to inefficient spectrum use, as it may complicate a national operator’s device strategy and impose additional interference-mitigation measures at the boundaries of concession areas. However, this need not be distortive, provided operators who so wish have a reasonable opportunity to aggregate national holdings that are contiguous across regions.

3.3 Reserve prices and licence payment terms

Artificially high reserve prices are prone to distort auction outcomes and harm the public interest in a number of ways:

- **Spectrum may be left unsold and unutilised representing a productivity loss to the State;**
- **An unnecessarily high cost-burden may be imposed on the industry, leading to adverse downstream consequences;**
- **National imbalances in spectrum holdings may be exacerbated.**

3.3.1 Failure to attract bidders

Artificially high reserve prices carry the risk that valuable spectrum resources are left unsold. Depriving mobile communications markets of key inputs comes at significant economic and social cost. While this may not matter for other State resources that are subject to competition (such as minerals), spectrum is consumed on an ongoing basis. If it is left idle during a period when it could have been used productively, that economic loss is permanent. Some examples of incomplete allocations that may be ascribed to artificially high reserves are provided below.

- **In India, successive failures to fully allocate the available 1800MHz spectrum between 2012 and 2014 have led to delays in its deployment. Policy in this market is akin to a descending 'Dutch auction', whereby the reserve price is reduced progressively over successive iterations. Each failed attempt postpones the economic benefits associated with the commercial use of this resource. This issue might not have occurred if moderate reserves had been applied from the outset, allowing the market to determine the final prices paid. On a population-weighted basis, the (lower) 2014 reserve price for 1800MHz in India was still $0.12 per MHz per head of population, which seems high in a market with average revenues of just $2.5 per customer per month[11].**
- **Due to the adoption of high reserve prices in the 2013 Australian Digital Dividend auction ($1.25/MHz/pop for 700MHz), a third of the prime 700MHz band was left unsold. This has created an intractable problem for the regulator. The government indicated prior to the auction that operators should not expect unsold spectrum to be made available at a lower price in the future[12]. This potentially blocks a transition to an Indian-style 'Dutch auction' for the unsold spectrum. Telstra and Optus, who paid the high reserve price, could challenge a discounted future award on the grounds that this is contrary to government statements upon which they relied during the original auction. While a refund might resolve the conflict, handing money back to operators is likely to be politically difficult. It is therefore possible that the unsold 700MHz will lie fallow for a considerable period, to the detriment of the Australian economy and consumers.**
- **In Bangladesh, a total of three blocks of 2x5MHz at 2100MHz failed to attract any bids during the 3G auction in 2013. This represents 37.5% of the 40MHz available during the auction. The high reserve prices in relative terms ($0.07/MHz/pop for a market generating less than $2 per customer per month) were likely to be the main cause, albeit ongoing tax disputes and other regulatory uncertainties may have contributed to this outcome[13].**

The economic impact of unsold spectrum in two specific instances (the auctions of 850MHz and 1800MHz spectrum in India and of 2100MHz in Bangladesh) is quantified in section 4 of this report.

11 Sources: Coleago analysis based on data from www.dot.com (reserve price); GSMAi estimates (average revenues per subscriber).

12 The Australian Financial Review provided the following quote from Minister Conroy on 7 May 2013: "The ACMA has previously stated that it should not be assumed any unsold spectrum would be returned to market in the short term, or at a price that is lower than the reserve price set for this auction [...] I endorse that as a sensible view."

13 See for example: http://www.cellular-news.com/story/61904.php.

3.3.2 Reserve prices as instrument to fund the state

If actual spectrum prices are dictated by reserve price rather than by competitive bidding at auction, then the spectrum-fee burden incurred by operators is likely to exceed the values that alternative users would place on these licences. This is potentially distortive insofar operators pay more than required to justify their allocations. Increased spectrum rents exacted by the state exacerbate the risk of adverse consequences in downstream markets.

During 2013 for example, winning bidders paid the reserve prices for 800MHz spectrum in Belgium and for 700MHz in Australia –respectively $0.74/MHz/pop and $1.25/MHz/pop. This is 12% and 89% more than was paid in the preceding UK multiband auction for comparable spectrum[14]. The regulators in Belgium and Australia may have anticipated limited contention for the available lots, but it seems unreasonable to impose prices that exceed those actually achieved in a recent, competitive auction. As outlined in section 2.2 above, only a moderate proportion of this extra cost needs to be passed on by operators in the form of higher downstream prices and/or curtailed network investment to offset the social gains from increased spectrum-fee receipts.

EXHIBIT 6: IMPACT OF HIGH RESERVE PRICES

Potential impact	Examples	Severity	Scope to mitigate
Spectrum remains unsold	India 850MHz (2012, 2013) Australia 700MHz (2013)	High High	Low Low
Higher costs are imposed on operators than necessary	Australia 700MHz (2013) Belgium 800MHz (2013)	High Medium	Low Low

Source: Coleago Consulting

3.3.3 Potential competitive distortions

High reserves also have the potential to distort the distribution of spectrum among operators. Notwithstanding competition safeguards such as spectrum acquisition caps, if vital spectrum resources are priced beyond the reach of credible market challengers, their ability to compete effectively could be impaired. While the competitive implications of spectrum policy lie outside the main focus of this report, regulators should nevertheless take this risk into consideration in their policy making.

The scope for operators to mitigate artificially high reserve prices during the auction is low. Their only choices are to accept the price, walk away or reduce the quantity of spectrum that they acquire –none of which represents a satisfactory outcome.

14 Prices per MHz per head of population, based on 30 June 2013 exchange rates. The corresponding UK figure ($0.66/MHz/pop) is the linear reference price calculated for 800MHz without the competition constraint. Sources: ACMA, BIBT, Ofcom (available here); historical exchange rates sourced from www.xe.com.

3.3.4 Scheduling of licence fee payments

A further relevant aspect is the scheduling of licence fee payments. In some cases, regulators require settlement in full immediately after the auction such as in Australia and the Netherlands. In others, such as following the Belgium and New Zealand Digital Dividend auctions, operators were able to pay the fees in instalments over an extended period.

In principle, operators can reflect the timing of payments in their valuations. However, requirements to pay the full amount as a lump sum may have a disproportionate impact on more highly geared operators, which could threaten allocation efficiency. Offering the option of upfront versus staggered payments (subject to a market-based interest rate) reduces this risk and should therefore be deemed best practice. The New Zealand Minister of Communications and Information Technology, Amy Adams, observed further that:

> *"Allowing staged payment will enable mobile network operators to invest immediately in building their 4G networks to increase their service to New Zealanders[15]."*

3.4 Scheduling of spectrum awards

Key questions that policy-makers need to consider include:

- **Can spectrum be awarded too soon?**
- **Is it better to award incremental spectrum in different bands simultaneously or sequentially?**

Spectrum utility is highly dependent on the maturity of the technology within relevant bands. Accelerated awards such as those for 700MHz in Tonga, Papua New Guinea, Australia, New Zealand and Chile may seem premature, given the current weakness of the 700 MHz ecosystem and the fact that these markets might arguably lack the scale to drive its development.

However, early awards do not pose a problem if the cost of securing these resources in advance is moderate, as was the case in most of these markets. Elsewhere, having to advance large sums for spectrum long before it can be exploited will undoubtedly be an issue which will influence participation in a spectrum auction. While timing is an aspect that can be factored into bid values, if capital is constrained, a potentially efficient user may effectively be excluded. Allowing for deferred payment would help mitigate this risk.

In regard to the second question, simultaneous awards offer operators the opportunity to make trade-offs between different quantities of spectrum in different bands. This promotes allocation efficiency. In contrast, sequential processes may hamper the aggregation of optimal spectrum portfolios by operators.

Taking all of the above into account, simultaneous awards of incremental spectrum seem preferable, even if the use of some of the resources on offer is deferred. This offers operators greater certainty over their holdings, which facilitates the development of optimal deployment strategies. In conjunction with appropriate licence fee payment terms, this would reflect best practice.

15 700MHz auction announcement, Sep 2013.

3.5 Choice of auction format

The key goal of any auction, in the words of the New Zealand MBIE, is "to guide goods to those who value them the most"[16]. Whoever values the resources the highest might be expected to put these to the most productive use. An auction mechanism is deemed efficient if it fulfils this goal.

3.5.1 Auctions for a single licence

If a single licence is available, regulators tend to rely on a Sotheby's-style (English) rising clock auction or on a sealed-bid format. A sealed-bid auction may either use a first or a second-price rule.

Under the first-price rule, winners pay the amount of their winning bids. This may lead to a 'winners curse': paying more than would have been required to win. This threatens auction efficiency. As observed by Ofcom: *"Under a first price rule, there is an incentive for bidders to reduce the value of their bids to less than their full valuation in order to pay as close as possible to the minimum necessary to beat other bidders (bid shading). By so doing, they risk not winning at all when it would be efficient for them to do so"*[17]. This yields an uncomfortable trade-off between minimising the risk of losing and minimising the 'winners' curse'. The 1998 Brazilian auction for 2G licences provides a palpable example of this problem: BellSouth paid $1bn more than the next highest bidder for the Sao Paulo Metro licence.

The introduction of a second-price rule eliminates this particular problem. Under the latter, the winner pays the amount of the next highest bid. A Sotheby's-style English auction approximates the second-price rule: prices stop rising when the second-highest bidder drops out. This incentivises truthful bidding: there is no penalty for bidding full value, because winners pay no more than the minimum required to justify their allocation. If all participants bid their true values, the auction will be efficient in identifying the highest value user of the resource. Moreover, if the two highest valuations are relatively close, this may generate higher proceeds than a first-price auction in which participants shade their bids.

Because they promote allocation efficiency, second-price formats are vastly to be preferred when awarding single licences.

3.5.2 Simultaneous award of multiple spectrum licences

The main formats used to auction multiple spectrum blocks are the Combinatorial Clock Auction (CCA), which uses a generalised second-price rule[18], and the Simultaneous Multiple Round Auction (SMRA). Sealed bid formats are sometimes adopted, such as the Combinatorial Second Price Auction[19] and the Combinatorial First-Price Auction (see R. Marsden, 2011 for a description of each of these[20]).

Under a given set of circumstances, each of the above may produce widely differing outcomes. While no format appears to be perfect, policy-makers need to consider the following potential sources of distortion:

1. **Inefficient allocations caused by fixed budget constraints in conjunction with a lack of visibility over price exposure;**
2. **Material price disparities between bidders for comparable packages;**
3. **Risk of predatory bidding strategies designed to raise the costs incurred by rivals;**
4. **Inefficiencies caused by difficulties in aggregating optimal spectrum packages;**
5. **Inefficiencies caused by demand moderation strategies.**

16 700 MHz Auction – Consultation on Auction Design and Implementation Requirements, and Execution', Ministry of Business, Innovation and Employment, May 2013.

17 Ofcom: Annexe 9 to the Consultation on 800MHz and 2.6GHz Competition Assessment and Award Proposals, Section 9.42, March 2011.

18 In second-price auctions for multiple lots, winners pay the cost of depriving rivals rather than their own winning bid values.

19 This uses the same mechanism as the CCA to determine winners and prices. Our comments on the CCA apply equally to this format.

20 'Introduction to spectrum auctions - A presentation for the GSMA Members Annual Spectrum Seminar', 2011.

Our view is that the CCA format is generally vulnerable to the first three of these forms of distortion[21], SMRA to the last two, and Combinatorial First-Price auctions to the first, second and the last.

EXHIBIT 7: KEY VULNERABILITIES OF THE MAIN AUCTION FORMATS

Format / Vulnerability	CCA	SMRA	Combinatorial First-price
Distortions when bidders are constrained by fixed budgets	■		■
Material price disparities	■		■
Risk of predatory bidding strategies	■		
Aggregation risk		■	
Demand moderation strategies		■	■

Source: Coleago Consulting

Following the 2013 UK multiband award, which used a CCA mechanism, the National Audit Commission (NAO) observed that two bidders appeared to be subject to fixed budget constraints and that this may have prevented them from achieving all their objectives. This potentially limited the efficiency of the auctionGotham[22].

The issue in a CCA is that participants have limited visibility over their actual price exposure: the bids of rivals, which determine the price they pay if they win, are not disclosed. This introduces a potentially intractable strategic dilemma for bidders who are constrained by a fixed budget rather than by their spectrum valuations. To minimise the risk of being knocked out, such bidders may choose to bid full valuations on smaller packages. Yet in so doing, they would squeeze the extra amount they can bid for additional lots, while staying within their overall budget limit. This would reduce their chances of winning the extra lots. As a result, they may fail to secure the larger package that, given the relative valuations and constraints of each participant, they actually ought to win. The opposite strategy open to management is to bid the available war chest on a larger package and reduce the bid values for smaller packages. This would increases the chance of winning a more ambitious prize, but also the risk of walking away with nothing.

Given the resulting threat to efficiency, the NAO recommended that UK regulator Ofcom "select designs for future auctions that take account of the circumstances of likely bidders, such as the likelihood that they will be subject to budget constraints"[23].

Since prices in a CCA are determined by the marginal bids of rivals, there is a potential for pricing asymmetries. For example, Swisscom secured a larger package yet paid a lower amount than Sunrise during the Swiss multiband auction in 2012. The limited feedback between what one bids and what one pays may also invite bid strategies designed to impose higher costs on competitors.

21 See in particular M.Janssen and V.Karamychev, 2013, 'Gaming in Combinatorial Clock Auctions' (available here), and the National Audit Commission's report following the 2013 UK multiband auction.

22 NAO, March 2014: '4G radio spectrum auction: lessons learned', ibid.

23 Ibid.

If multiple bidders engage in this strategy (as they might simply to avoid adverse pricing differentials), they could all end up paying more on aggregate. The exceptionally high spectrum prices generated in the multiband auctions in the Netherlands (2012) and Austria (2013) could plausibly be a product of such dynamics. The high burden of spectrum fees in these cases could have significant downstream consequences for consumers. Such outcomes are less likely if bidders incur a cost when they raise prices for rivals, as is typically the case in an SMRA.

EXHIBIT 8: DISTORTIONS UNDER THE CCA FORMAT

Potential impact	Examples	Severity	Scope to mitigate
Potential inefficiency due to fixed budget constraints	UK multiband (2013)	High	Low
Higher spectrum costs	Netherlands multiband (2012) Austria multiband (2013)	High High	Low Low
Price disparities	Switzerland multiband (2012)	Medium	Medium

Source: Coleago Consulting

The SMRA format introduces different threats to efficiency. First, since participants bid on individual lots rather than on entire combinations, it is possible to win an unwanted subset of a target package. Management's need to manage this risk may distort bid behaviour. If the lots reflect specific frequency ranges rather than generic quantities within a given band, there is also a risk of fragmented assignment, which is technically inefficient. Neither issue arises in a CCA or in a first-price sealed-bid auction, because participants in these either win a whole package-bid or nothing at all.

Secondly, SMRA may be construed as a tacit negotiation between the auction participants: the quicker everyone agrees on who gets what, the less bidders will pay collectively. While demand-moderation strategies are rational, these may impact spectrum auction revenues. However, if an efficient allocation is the prime objective, policy-makers should be less concerned about the impact on auction receipts – which will be, in part, self-correcting through corporate taxation. Nor does demand moderation necessarily lead to a suboptimal distribution of resources: if bidders are realistic and correctly gauge relative spectrum valuations, the outcome may indeed be the most efficient one.

CCA and SMRA both have disadvantages; however, the Combinatorial First-Price Auction introduces even greater risks. One argument in favour of the latter is that it tends to attract wider participation. This is because uncertainty surrounding incumbent strategies may create an opportunity for entrants to 'sneak a win'[24]. In an era of general consolidation among mobile network operators, this seems a questionable benefit. It is also likely to be more than offset by the increased risk of inefficiency due to bidder concerns around winner's curse, as described in section see 3.5.1 above.

Combinatorial First-Price auctions also share the following key drawbacks with the CCA format:

- **Increased knock-out risk, because bidders are unable to respond to unforeseen events (this risk is further exacerbated by the incentive to shade bid values in order to minimise the winner's curse);**
- **Risk of price disparities;**
- **Risk of distortion caused by budget constraints.**

24 See R.Marsden, 2011 (ibid).

The dilemma for budget-constrained bidders is similar to that in a CCA, because the winner determination algorithm (if not the price-setting) is identical. The winning allocation is that which corresponds with the highest combined bid value. Bidders need to express a sufficiently high value-differential to win a larger rather than a smaller package. As under CCA, fixed budget constraints may prevent this if bidders focus available cash on the smaller package to minimise the risk of knock out: the amount that can be bid for extra lots is reduced. In short, Combinatorial First-Price auctions appear to reflect the worst of all worlds.

EXHIBIT 9: POTENTIAL DISTORTIONS IN (COMBINATORIAL) FIRST-PRICE AUCTIONS

Potential impact	Examples	Severity	Scope to mitigate
Winners' curse	Brazil 2G licences(1998)	High	Low
Increased knock-out risk	Norway multiband (2013)	High	Low
Price disparities	France 800MHz (2011)	Medium	Low
Further inefficiency due to fixed budget constraints	No example in public domain, but risk exists in all cases	High	Low

Source: Coleago Consulting

Combinatorial First-Price auctions are the most distorting of the main auction approaches and should be avoided. Opinions will differ on whether CCA or SMRA is more prone to distortions overall. The relative levels risks will also depend on circumstances as well as the detailed rules. Regulators should examine their national circumstances and reflect feedback from operators in their ultimate choice of format.

3.6 Licence terms and regulatory landscape

Spectrum valuations will be influenced by licence terms and conditions such as:

- **Licence duration and expected future policies relating to expiring usage-rights;**
- **Technological conditions (e.g. technology-specific versus neutral licences);**
- **Coverage obligations;**
- **National roaming and/or wholesale provisions.**

Provided reserve prices are not excessive, such licence conditions should, in general, not prejudice auction efficiency, since operators have ample scope to correct for these by adjusting their bids.

However, technological restrictions may represent a notable exception in this regard. The 850MHz award that was launched in India in 2012 for example, effectively ruled out EGSM or LTE use. The EGSM-compatible portion was already occupied by CDMA operators, and provisions to reassign their holdings to the lower end of the band were lacking. The fragmentation of the band also hindered the acquisition of contiguous ranges of sufficient size for efficient LTE deployment. Furthermore, while the incremental 850MHz spectrum was ostensibly available on a technology neutral basis, the previously allocated spectrum had not been liberalised. This led to the auction being postponed due the failure to attract bidders. It was finally held in March 2013, during which a fraction of the available lots were secured by a single participant in just 8 of the 22 circles where spectrum was being offered.

Regulatory uncertainties may also influence auction outcomes. Policies on licence renewal, for instance, can have a significant impact on bid values because they affect residual cash flows beyond the licence term. A potential misallocation may thus arise if inefficient spectrum users take an optimistic view, while more efficient users remain cautious. Although the same may be said of any assumption, policy-makers should be in a position to avoid this distortion by specifying renewal conditions prior to auction.

3.7 Conclusions

Policy choices in most areas have the potential to influence spectrum auction outcomes. However, greater attention should be given to those aspects that carry a higher and avoidable risk of distortion, and that are more difficult for operators to mitigate without harming public interests. These are summarised in the table below.

EXHIBIT 10: SUMMARY OF KEY DISTORTIVE POLICIES

Potential impact	Examples	Potential severity	Scope to mitigate
Explicit or de-facto spectrum reservations	Unsold spectrum Inefficient use Unduly high costs for incumbents	High High High	Low Low Low
High reserve prices	Unsold spectrum Unduly high costs for operators flowing to downstream markets Exclude efficient operators	High High High	Low Low Low
Inefficient lot sizes	Spectrum and technology fragmentation	High	Medium[a]
Use of specific lots only	Technical inefficiency due to fragmented holdings	Medium	Medium[a]
Lots include expiring usage rights	Risk to business continuity Risk of predatory bidding Note: risk may be reduced with suitable spectrum floors[b]	High Medium	Low[a] Medium
First-price sealed-bid auction format	Winners' curse v Knock-out risk Price disparities Risk of inefficiency if bidders have fixed budget constraints	High Medium High	Low Low Low
Technological restrictions	Risk of unsold spectrum Risk of inefficient deployment	High High	Low Low
Regulatory uncertainty	Increased risk of misallocation Risk of unsold spectrum	High Medium[c]	Low Low

Source: Coleago Consulting
Notes: a Subject to auction format and rules.
b The level of risk and suitable mitigation depends on the proportion of spectrum in use that could be reassigned to alternative users.
c Subject to the reserve prices. Even 'reasonable' reserves may appear too high if regulatory risk unduly depresses spectrum valuations.

As outlined in the following section, the economic cost of inefficient spectrum allocations is readily quantifiable when they can be translated into a reduction in industry capacity and hence spectrum productivity.

The issues highlighted above reflect policy choices that increase the risk of distortion. However, regulatory measures that mitigate these risks or otherwise promote favourable outcomes should also be considered in a review of relevant policies.

These include the following:

- **Applying spectrum floors in the event spectrum-in-use is being re-auctioned, to minimise the threat to business continuity;**
- **Aligning reserve prices with the higher of (a) the costs of freeing up the spectrum for mobile use[25] or (b) the valuations based on alternative industry uses, to avoid imposing unduly high costs on the industry (that might otherwise be passed on to consumers in the form of higher retail prices or reduced investment and innovation);**
- **Providing deferred licence fee payment terms to equalise the opportunity for operators to secure the resources they need to pay for spectrum, in light of possible differences in their ability to raise substantial funds in advance;**
- **Modifying auction rules to minimise the scope for predatory bidding strategies designed to drive higher costs for rival bidders;**
- **Imposing 'use it or lose it' provisions in the form of non-band specific coverage obligations to minimise the threat of spectrum hoarding, particularly where spectrum is awarded at a discount to entrants via a set-aside; for example, band-agnostic coverage obligations would minimise the risk that entrants secure spectrum with the aim to hold and sell at a premium;**
- **Ensuring early industry participation when preparing/deciding on spectrum award procedures and ensuring adequate transparency level for all auction participants throughout;**
- **Avoiding the use of auctions when an obvious distribution of available resources among operators can be readily identified, to minimise the risk of perverse outcomes.**

With respect to the last point, we would observe that where there is an obvious distribution of available resources among a small number of market participants, an administered process may be more appropriate. It is always possible to maintain an auction mechanism as a 'fall-back option' in the event of a dispute or a credible challenge to the process.

25 For example, the New Zealand government spent NZ$157 million clearing the 700MHz band to allow mobile use. The reserve price in the 700MHz was set slightly above this (NZ$198 million in total for nine blocks. Source: 700MHz auction 2013 announcement by Communications and Information Technology Minister Amy Adams, 4 Sep 2013.

4. Social and economic impact of inefficient spectrum allocations

4.1 Sources of consumer harm

Mobile spectrum underutilisation resulting from artificial scarcity or inefficient distribution among operators hampers the growth in industry capacity, potentially leading to increased network congestion. The latter invariably leads to curtailed or at best delayed communication. In addition, supply-side constraints may result in higher retail prices.

Inefficient spectrum allocation can lead to increased network congestion. This not just a nuisance, it has a significant economic cost.

Spectrum allocations that lead to competitive distortions reflect another form of inefficiency. Impaired competition may also result in higher retail prices, as well as reduced investment, innovation and consumer choice. These too are likely to depress the adoption and consumption of mobile services.

In some cases, inefficient uses of spectrum may delay the technological evolution in a market. Mobile broadband represents an important platform for access to digital services, whose adoption and use can be impeded by suboptimal deployment of cellular technologies.

4.2 Impact of telecoms adoption on GDP growth

The positive influence of telecommunications on economic productivity is well documented. In this section, we focus on the results of a number of econometric studies that establish a relationship between GDP growth and the adoption of fixed, mobile, 3G and broadband communications.

Waverman, Meschi and Fuss (2005) estimate that a 10 percentage-point increase in mobile penetration in a developing country could boost GDP growth by 0.59 percentage-points[26]. This is based on a regression analysis of data from 102 low and middle-income countries between 1995 and 2003. According to their research, mobile adoption also yields a significant, albeit lower GDP growth dividend in developed markets.

Qiang (2009) refers to a more recent World Bank study that correlates GDP growth with fixed, mobile, internet and broadband adoption[27]. This research suggests that a 10 percentage point increase in mobile penetration could generate a 0.81 percentage point increase in GDP growth in low-to-middle income countries, and a 0.60 percentage point increase in high-income countries. The result for broadband adoption is even more dramatic: a 10 percentage point increase in penetration yields a 1.38 percentage point increase in GDP growth in low-to-middle income countries, versus 1.21 percentage points in high-income countries.

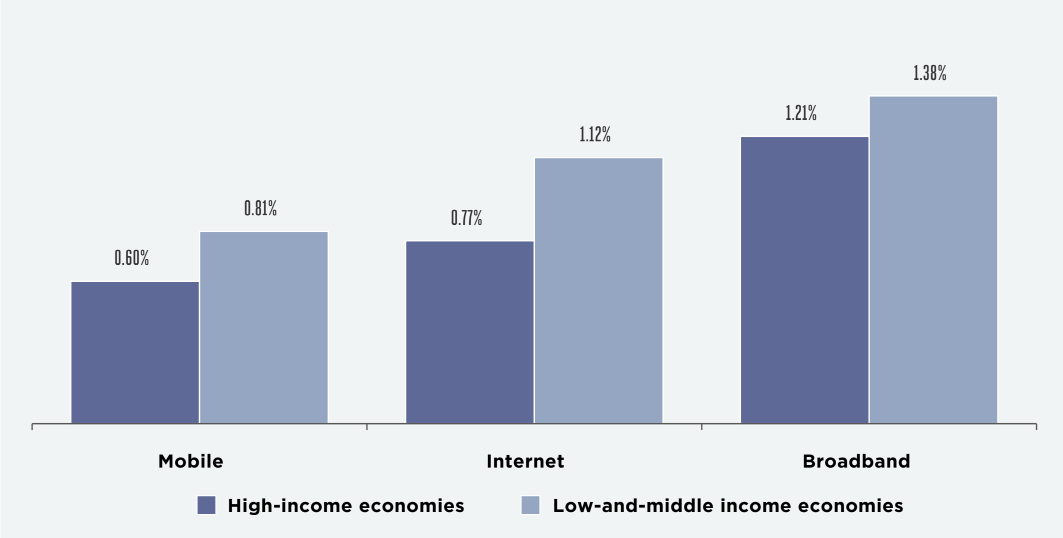
It should be noted that these results were generated using data prior to 2007. Mobile SIM penetration across the globe has increased dramatically since, and one might expect the marginal economic benefits of mobile adoption to decline. In particular, the rise in multiple-SIM ownership, which should have a negligible impact on GDP growth, accounts for an increasing proportion of mobile penetration. However, this does not mean there is no incremental benefit to further adoption. Average mobile penetration in the poorer half of countries today is almost identical to the 2006 average in the richer half[28]. Accordingly, the 0.60% factor that applied to mobile penetration in high-income in 2006 may plausibly apply to low-and-middle income economies today. We take this to be the case in our further analysis. As far as broadband is concerned however, where penetration levels remain low or modest, the above relationship between adoption and GDP growth may reasonably be expected to hold.

26 Waverman, Meshi and Fuss, 'The Impact of Telecoms on Economic Growth in Developing Countries', The Vodafone Policy Paper Series, Number 2, March 2005, available on the World Bank website.

27 'Mobile Telephony - A Transformational Tool for Growth and Development', 2009, Christine Zhen-Wei Qiang, Proparco's Magazine.

28 Average mobile SIM penetration in the wealthier half grew from 83% in 2006 to 129% in 2013, while average penetration in the poorer half grew from 25% to 81% over the same period. Source: Coleago Consulting analysis based on World Bank 'World Development Indicators' data.

EXHIBIT 11: INCREASE IN GDP GROWTH FOR A 10 PERCENTAGE POINT INCREASE IN PENETRATION



Source: Coleago Consulting

Finally, a 2012 report by Deloitte for the GSMA in association with Cisco concludes that a 10 percentage point substitution of 2G for 3G penetration raises GDP growth by 0.15 percentage points[29]. Note that 3G SIM adoption does not always result in mobile broadband use: this result does not conflict with the World Bank research. Deloitte's study suggests further that a doubling in data usage per 3G connection across a sample of 14 emerging and developed countries would lead on average to a 0.5 percentage point increase in GDP growth.

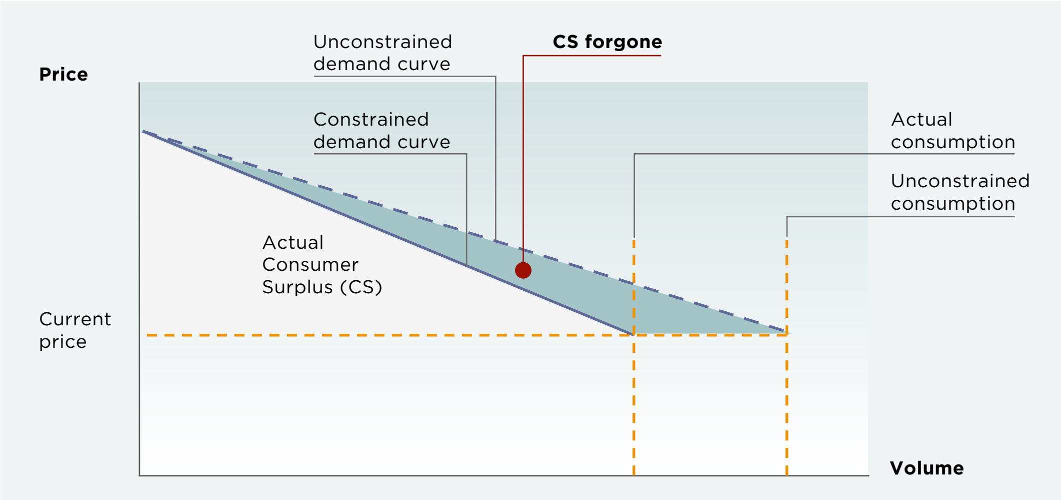
4.3 Economic impact of congestion

Inefficient spectrum allocation or use can exacerbate network congestion. This is not just a nuisance: it has an economic cost. Swift access to information and the ability to transact quickly drive economic productivity. Impeded communications lead to inefficiency. To use an analogy, a very bad road between two cities might not block the transfer of goods between the two, but it may lead to costly delays. Accidents and mishaps are more likely, and fewer goods might be conveyed on aggregate, hampering commerce.

Network congestion also reduces Consumer Surplus (CS): demand is then constrained by capacity rather than just by price. This can be determined empirically. The CS foregone as a result of this is given by the area between the unconstrained and constrained demand curve and the actual consumption curve, as illustrated conceptually in Exhibit 1 below.

29 "What Is the Impact of Mobile Telephony on Economic Growth?", 2012.

EXHIBIT 12: IMPACT OF CONGESTION ON CONSUMER SURPLUS (CS)



Source: Coleago Consulting

The actual Consumer Surplus (CS) is the difference between the price consumers would be willing to pay for their usage, and the price actually paid. Following the methodology used by Hazlett et al, a lower bound for the (constrained) demand curve can be gauged by comparing historical consumption volumes against historical prices[30].

In the absence of congestion however, customers would have been able and willing to fulfil their own demand, generating a higher surplus at the prevailing prices[31]. To construct the unconstrained demand curve within this framework, one needs to make assumptions about the degree to which congestion limited consumption in the past. The lost Producer Surplus (PS) is effectively the lost revenue minus the incremental costs that would have been incurred to serve the additional demand. Together, the lost CS and PS represent the total Economic Surplus foregone. Our assessment of the impact of inefficient spectrum allocation on Economic Surplus in India is given in section 4.5.1.

4.4 Calculating the economic cost of mobile network congestion

To determine the economic cost of mobile network congestion, we first need to consider its effect on total industry capacity. Comparing the latter with potential (i.e. unconstrained) demand allows us to express the inefficiency in terms of foregone consumption.

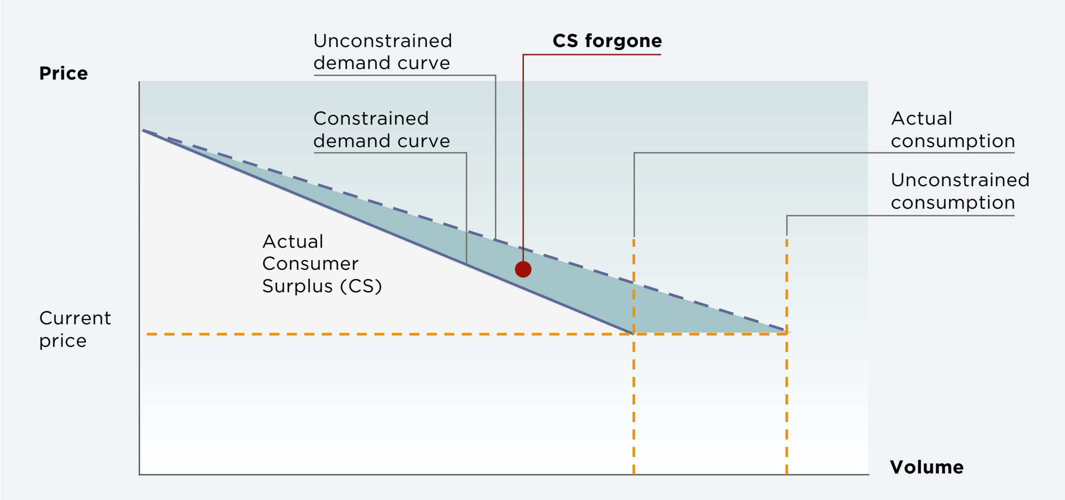
Exhibit 13 below illustrates our approach. In unconstrained networks, busy-hour demand is invariably heavily skewed: a minority of sites carry a disproportionate amount of traffic, while the majority operate below maximum capacity. The shape of this unconstrained busy-hour demand distribution across the network tends to be similar across different markets. However, congestion alters this picture: any demand above capacity on any individual site is truncated. This results in a flattened, constrained traffic-distribution across the network. This applies both to individual networks and to the industry as a whole.

30 See Thomas W. Hazlett, Roberto E. Muñoz, and Diego B. Avanzini, "What Really Matters in Spectrum Allocation Design", 2012, 10 Nw. J. Tech. & Intell. Prop. 93, (page 6).

31 The fact that customers would be willing to consume greater quantities follows from the fact that demand exceeds the supply of capacity.

The maximum capacity per site needs to take non-spectrum enhancements into account, such as the likely scope for network densification. If total busy-hour traffic and the maximum network capacity are both known, it is possible to construct the corresponding unconstrained busy-hour demand distribution.

EXHIBIT 13: IMPACT OF REDUCED INDUSTRY CAPACITY ON BUSY-HOUR CONSUMPTION



Source: Coleago Consulting

The area between the unconstrained and constrained traffic-distributions yields the busy-hour traffic lost due to congestion. Increased efficiency of spectrum use raises average capacity per industry site, and thus reduces the total amount of busy-hour traffic-demand lost to congestion. The shaded area in the graph above represents the extra amount of busy-hour traffic that would be served in the market if spectrum is allocated efficiently.

To determine the total amount of traffic foregone, we also need to consider the average daily traffic profile on individual sites. For example, there may still be congestion in the second and third busiest hours, while off-peak traffic is unhindered. Adding up the traffic lost to congestion in each hour of the day yields the total traffic lost to congestion.

Once the percentage of total traffic lost to congestion has been determined, we can then compute the impact on Economic Surplus as described in 4.3.

4.5 Case studies

Our estimates of the economic cost of inefficient spectrum allocations in India, Bangladesh and Chile are provided below. The underlying network and traffic assumptions are described in the appendix.

4.5.1 India (850MHz, 900MHz and 1800MHz awards)

The cost of inefficient spectrum allocation in India is in the order of $3.6 billion per annum on foregone Economic Surplus.

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The Indian government launched a series of auctions between 2012 and 2014 for 850MHz, 900 MHz and 1800MHz spectrum:

- **All 900 MHz spectrum offered was sold;**
- **Between 10MHz and 13.75MHz paired at 1800MHz was auctioned in each of the 22 telecom circles in November 2012, of which 40% was unsold (on a population-weighted basis);**
- **Between 3.75MHz and 5MHz paired at 850MHz was auctioned in each of the 22 circles in March 2013, in which around 70% of the available spectrum was unsold[32];**
- **A total of 16.6MHz paired at 1800MHz (on a population-weighted basis) was auctioned in February 2014, of which 25% remained unsold.**

Following the successive 1800MHz awards, 17% of the combined total available remains unallocated. Furthermore, only half of the 850MHz band is currently in use, exclusively for CDMA[33]. The number of CDMA customers served per MHz is half that of GSM, leading to further inefficiency[34]. Supposing two thirds of this spectrum could be reallocated for GSM; then based on these numbers, efficiency would increase by 67% and would be maximised.

To estimate the economic cost of the inefficient allocation of spectrum in India, we consider two cases as shown in Exhibit 14 below. The Factual case reflects the current situation. The Counterfactual assumes that the spare 9.5MHz at 850MHz plus the unsold 4MHz at 1800MHz are allocated, increasing industry holdings by 13.5MHz on a population-weighted basis.

EXHIBIT 14: FACTUAL AND COUNTERFACTUAL SPECTRUM CASES

National average (2xMHz)	850MHz	900MHz	1800MHz	Total
Factual	10.5	19.5	44.0	73.9
Counterfactual	20.0	19.5	48.0	87.4

Source: Coleago Consulting

In the counterfactual scenario, we also assume that 50% of the existing 850MHz plus the spare 9.5MHz is allocated for E-GSM or 3G. Taking into account the relative efficiency factors based on customers per MHz, the factual scenario is equivalent to 66.8MHz fully allocated to GSM, increasing by 19.8MHz to 86.6MHz paired in the counterfactual. For ease of computation, we assume further that all the voice traffic in the market is carried on these bands, and none of the data traffic.

Our analysis yields the following results:

- **20% of busy-hour voice traffic and 9.5% of total annual voice traffic is lost to congestion in the factual case;**
- **The counterfactual spectrum scenario would allow the industry to serve an extra 9.6% of busy-hour voice traffic and an extra 4.8% of total voice traffic;**
- **Constrained voice usage is estimated at 370 minutes per customer per month, hence efficient spectrum allocation would allow the industry to serve an extra 18 minutes per customer per month;**

32 The auction followed an earlier attempt in November 2012 which failed to attract any bidders.

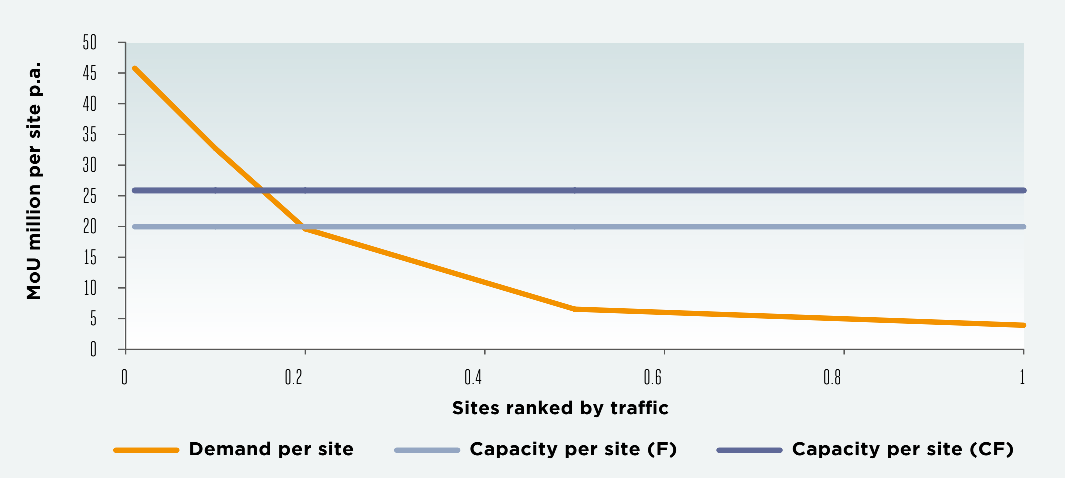
33 The total in use is 10.5% on a population-weighted basis, yet the size of the band is 2x20MHz according to section 2.2 of the Consultation Paper No.13/2013 issued by the TRAI.

34 Source: Coleago analysis based on GSMi data for Q4 2013.

The graph in Exhibit 15 below illustrates our analysis. The area bound by the demand-per-site curve and the capacity-per-site lines for the factual (F) and counterfactual (CF) cases represents the total busy-hour voice traffic lost to congestion.

To calculate the impact on Consumer Surplus (CS), we need to determine both the constrained and unconstrained demand curves. The constrained demand curve is determined by comparing historic consumption volumes and prices. Congestion has been a problem in India for many years, albeit it may have been caused by other factors than spectrum shortages in the past. Assuming that congestion constrained historical consumption to at least the same extent as it does today, we can construct an unconstrained demand curve by adding 4.8% to the consumption volumes over time. Using GSMAi data from 2002 to 2014, this approach yields a loss in Consumer Surplus due to inefficient spectrum allocation of $2.7 billion per year.

EXHIBIT 15: BUSY-HOUR TRAFFIC VERSUS INDUSTRY CAPACITY



Source: Coleago Consulting

The Producer Surplus (PS) foregone is calculated as the extra revenues that would have been generated by the extra traffic at the prevailing prices, minus the incremental costs. Using GSMi data, we estimate the revenues foregone at $1.1 billion. Assuming the extra spectrum in the counterfactual scenario were deployed on 30% of sites, and based on a five year amortisation period, we obtain an equivalent annual cost of $0.2 billion (see Appendix for the underlying assumptions). This yields a Producer Surplus impact of $0.9 billion per year.

Accordingly, we estimate the impact on total Economic Surplus (CS plus PS) at $3.6 billion per year.

To put these figures into perspective, consider the amount and value of spectrum sold at the reserve price. In the 1800MHz auction in 2014, a total of 6.8MHz (on a population-weighted basis) was sold at the reserve, yielding $2.6 billion. The 850MHz produced a further $1.2 billion, bringing the combined total to $3.8 billion. Had the reserve prices been zero, these lots would instead have been sold at their market value. Unsold lots might plausibly have attracted competing bidders too. Accordingly, the $3.8 billion raised by the state is the absolute maximum that could possibly be ascribed to the reserve prices alone.

EXHIBIT 16: SUMMARY

	Value
Economic Surplus foregone	$3.6 billion per year
Maximum theoretical proceeds attributed to the reserve prices	$3.8 billion one-off

Source: Coleago Consulting

We may conclude from this that the annual economic cost of unused spectrum far outweighs the additional auction proceeds that high reserve prices might plausibly have generated.

4.5.2 Bangladesh (3G award)

In Bangladesh, 2x50MHz at 2100MHz was made available to operators in 2013. 2x40MHz of this was put up for auction, while the remaining 2x10MHz was reserved for Teletalk, the state-owned operator, who would pay the auction-determined price.

A total of three blocks of 2x5MHz failed to attract any bids, amounting to 37.5% of the 2x40MHz on offer. This outcome exacerbates the severe spectrum shortfall in Bangladesh: industry holdings at 900MHz, 1800MHz and 2100MHz are around two-thirds of the harmonised bandwidth in these bands.

Furthermore, a total of 2x25MHz across these bands has been allocated to Teletalk, whose market-share has been fluctuating between 1% and 3% since its launch in 2005. Given this track-record, it seems unlikely that the company will suddenly capture a significant share in the foreseeable future. If this is indeed the case, its holdings will not contribute materially to overall industry capacity.

EXHIBIT 17: MOBILE NETWORK OPERATOR HOLDINGS

2xMHz	900MHz	1800MHz	2100MHz	Total
Harmonised band-size	35	70	60	165
Total allocated to MNOs	30	47	35	112
Total excluding Teletalk	25	37	25	87

Source: Coleago Consulting

Based on GSMA traffic and site data as of Q4 2003, and leaving out Teletalk's holdings, we estimate that voice congestion is around 9% of busy-hour traffic.

With increased diffusion of 3G-enabled handsets, deployment of 2100MHz spectrum will help alleviate voice congestion in the market. We estimate that 2x15Hz of 3G spectrum serving voice alone would reduce busy hour congestion from 9% to just 3%.

Assuming that the 2x10MHz effectively remaining in this band addresses future demand for mobile data, we estimate that 25.0% of the population could be served with an average consumption of 350MB per month[35]. The experienced quality would be very poor however, with 35% of busy-hour demand blocked by congestion.

35 According to Plum Consulting, 250MB reflects the minimum socially necessary use of broadband. See 'The benefits of releasing spectrum for mobile broadband in Sub-Saharan Africa', 2011. 350MB allows for variations between users above this threshold.

Efficient allocation of the unsold 2x15MHz at 2100MHz would increase the number of users that could be served with these consumption levels from 25.0% to 30.6%. This would represent a 5.6 percentage point increase in (mobile) broadband adoption. Moreover, the busy-hour congestion would be reduced from 35% to a more manageable 6.5%.
Applying the regression analysis described in section 4.2, this yields the following:

- **A 10 percentage point increase in broadband adoption boosts GDP growth by 1.38 percentage points;**
- **A 5.6 percentage-point increase in mobile broadband adoption would drive a 0.77 percentage point increase in GDP growth;**
- **This would equate to $1.0 billion in additional GDP growth per year ($21/MHz/pop).**

The annual economic cost is thus almost double the $525m raised in the 2013 auction as a one-off windfall gain[36]. Considering the average monthly revenues per customer are only $2 in Bangladesh, the $0.07/MHz/pop reserve seemed unduly high. The regulator may plausibly need to reduce the reserve to enable a sale and thus to ensure the economic benefits of the remaining three 2x5MHz blocks are realised.

4.5.3 Chile (AWS award)

By reserving AWS spectrum for new entrants, the Chilean regulator missed an opportunity to get an early head-start with LTE in the country.

Chilean regulator awarded 2x45MHz of AWS spectrum (1700MHz paired with 2100MHz) to two new entrants in September 2009. Incumbent operators were excluded from the process. Both newcomers deployed HSPA technology, despite the lack of a significant 3G ecosystem in this band. However, they had few options. First, roll-out and launch obligations meant they could not wait for the emergence of LTE in this band. Secondly, because they had no other spectrum, they lacked a Circuit-Switched Fall-Back option. Deploying LTE would have confined them to data-only propositions. The incumbents would not have been hampered by the latter. Four years after the award, one of the entrants closed its mobile operations, while the other serves less than 0.9% of the market. This result reflects an extremely inefficient use of prime spectrum. Critically, this delayed the introduction of LTE in the Chilean market by several years. In contrast, AWS LTE was introduced in Canada during 2011. By the end of 2011, 1% of handsets were LTE enabled, rising to 28% by Q4 2013. A comparison of the wider outcomes in both markets is provided below:

EXHIBIT 18: MOBILE BROADBAND ADOPTION IN CANADA AND CHILE

% of devices (Q4 2013)	Canada	Chile
GSM	19%	78%
HSPA	53%	22%
LTE	28%	-
Total mobile broadband	81%	22%

Source: Coleago Consulting, GSMAi

36 We exclude the fee paid by Teletalk from this calculation. Since Teletalk is state-owned, this fee does not provide a net contribution to public funds.

Our point is that the introduction of AWS LTE in Canada provided a significant boost to mobile broadband adoption: 15 percentage points of the net growth between 2011 and 2013 can be ascribed to this technology, or 23% in relative terms.

Fixed broadband penetration in Chile is low: 13% in 2013 (versus 34% in Canada)[37]. Accordingly, mobile broadband represents a significant opportunity to increase digital access. Suppose that AWS LTE had been available since 2011 in Chile and that its relative impact was the same as in Canada. A 23% relative increase between 2011 and 2013 would have generated a 3.0 percentage-point increase in the proportion of mobile broadband devices in Chile[38].

If we take the Deloitte regression analysis in section 4.2 and apply the result to substitution of GSM for LTE (rather than for 3G), we obtain the following:

- **A 10 percentage point substitution of GSM for 3G generates a 0.15 percentage increase in GDP growth;**
- **A 3.0 percentage point net increase in GSM substitution for LTE corresponds with additional GDP growth of $420 million per year ($0.26/MHz/pop).**

This should be taken as a lower-bound: LTE is far more likely to be associated with mobile broadband use than 3G.

Between 2011 and 2013, overall mobile SIMs in Chile grew by 11%. Accordingly, the 3.0 percentage point increase in the share of 3G and 4G SIMs would correspond with a 3.3 percentage point increase in mobile broadband penetration. Moreover, given the low fixed broadband penetration, such an increase would likely reflect net incremental broadband access.

By applying the results of the World Bank regression-analysis in Exhibit 11 for broadband adoption in high income countries, we obtain a plausible upper end to the economic valuation range:

- **10 percentage point increase in broadband penetration in a high-income country generates a 1.21 percentage-point increase in GDP growth;**
- **This generates additional GDP growth of $3.4 billion per year ($2.1/MHz/pop).**

In conclusion, the policy choice of awarding the AWS spectrum to new entrants rather than allowing incumbents to compete for these resources may have cost the Chilean economy between $24 and $192 per capita in foregone GDP growth per year. This also excludes further welfare benefits such as Consumer and Producer Surplus.

37 Source: OECD.

38 Source: Coleaago Consulting analysis based on GSMAi data.

5. Auction Distortion Report

5.1 Objectives and approach

The purpose of the Auction Distortion Report is to highlight potential risks introduced by policy choices in individual spectrum award processes. While this pilot version considers an international sample of six completed auctions, the proposed approach can also be used to assess awards in preparation. It is intended to provide an evidence-based platform to press for the adoption of best practices.

Generic aspects considered here correspond with those highlighted in section 3.7 above, as well as any idiosyncratic provisions that may apply to individual auctions.

Each item is assessed on the basis of the risk and potential severity of distortion, taking operator mitigation into account. The possible risk-scores are 'High', 'Medium', 'Low', 'Neutral' and 'Positive'. The latter would refer to a regulatory measure that materially reduces the overall threat to efficiency. Aspects that are deemed neutral are excluded from the risk scorecard. An overall assessment is given in the form of a combined risk-score, taking the individual components into account.

Generic risk-scoring criteria (for completed awards) are shown in the table below. Additional criteria will apply for aspects that are unique to a given auction.

EXHIBIT 19: GENERIC RISK SCORING CRITERIA

Policy choice	Criteria applied
Spectrum caps and set-asides	'High' risk if led to demonstrably inefficient spectrum use and/or prices over 120% of relevant benchmark prices. 'Medium' if spectrum is unsold as a result and a re-auction requires new legislation and/or changes to the band-plan. 'Low' if unsold spectrum was successfully allocated during a subsequent auction with inconsequential delay.
Reserve prices	'High' risk score if more than 120% of relevant benchmark prices, or if spectrum was unsold. 'Medium' if price was within 70%-120% of benchmark, or if there was unusually low demand for available lots. 'Low' if 40%-70% of benchmark. 'Positive' if less than 40% of benchmark.
Payment terms	'Positive' if licence fees are payable in instalments over 5 years or more (with reasonable interest rate).
Lot sizes	'High' risk if could result in holdings in any given band of less than 2x5MHz duplex (or 5MHz in the case of TDD).
Use of specific lots only	'Medium' risk if true
Lots on offer include expiring usage rights	'High' risk unless suitable mitigation provided (e.g. implementation of spectrum floors).
Use of first-price sealed bid auction	'High' risk score in the absence of mitigation for threat to efficiency.
Technological restrictions	'High' risk score if hampers progress towards more advanced technologies.
Regulatory uncertainties	'High' risk score if unusually severe uncertainties existed that plausibly depressed demand for spectrum on offer.

Source: Coleago Consulting

A similar approach may be used for forthcoming awards, although the assessment of certain elements will reflect past international experience rather than actual outcomes.

5.2 Sample auctions and summary of risk assessment

The sample auctions and our overall distortion assessment is summarised in the table below:

EXHIBIT 20: SUMMARY

Award	Risk score	Comments
India 850MHz and 1800MHz (2012, 2013)	High risk	This Indian auction failed to address chronic data and voice congestion in the market by maximizing the allocation of vital spectrum resources, causing substantial social and economic harm.
Australia 700MHz (2013)	High risk	The unusually high reserve prices may have contributed directly to 33% of the prime 700MHz band being left unsold.
Chile AWS (2009)	High risk	De facto set-aside of key spectrum for new entrants led to highly inefficient utilisation of valuable national resources.
Chile 700MHz (2014)	Positive	The policy focus on coverage and service commitments rather than spectrum fee receipts reduced the overall risk of distortion. The available spectrum was sold at low prices by international standards, and all operators had a fair chance to secure the resources they needed.
Canada AWS (2008)	High risk	Set-asides for new entrants led to inefficient use of spectrum as one new entrant never deployed, one is administration with a rapidly dwindling customer base, and a 3rd seeks to exit the market. The latter two deployed HSPA instead of LTE in the AWS band, thus reducing the capacity and speed of the spectrum.
Bangladesh 3G (2013)	High risk	The combination of high reserves and regulatory environment contributed to vital spectrum resources remaining unsold.

Source: Coleago Consulting assessment

The detailed assessment for each of these awards, including a description of the auction process and outcome, is provided in the following sections.

5.3 India 850MHz and 1800MHz auctions

Significant amounts of 850MHz and 1800MHz spectrum were left unsold during a series of auctions between 2012 and 2014.

The failure to allocate all available 1800MHz spectrum may be attributed to artificially high reserve prices. However, the lack of demand for 850MHz spectrum had multiple apparent causes.

- **De facto technological restrictions: severe fragmentation of the band among existing CDMA operators and the sale in lots of 2x1.25MHz hampered the acquisition of sufficiently large contiguous holdings for efficient E-GSM or 3G deployment;**
- **While the incremental 850MHz spectrum was ostensibly available on a technology neutral basis, the previously allocated spectrum had not been liberalised;**
- **Further regulatory uncertainties (notably surrounding licences that had previously been cancelled) may also have further dampened interest in the 850MHz band;**
- **The reserve prices for a significant number of lots were too high in the circumstances, especially given the regulatory uncertainty and the recurring attempts by policy-makers to extract unduly high fees from the industry.**

The economic cost of the unsold and inefficiently used spectrum is significant. As set out in section 4.5.1, the estimated Economic Surplus foregone is in the order of $3.6 billion per year.

EXHIBIT 21: INDIA 850MHZ AND 1800MHZ AUCTION SCORECARD

Policy	Risk score	Comments
Price	High risk	A total of 15% of the combined spectrum on offer was unsold.
Regulatory uncertainty	High risk	Lack of clarity around liberalisation, concerns around government policy toward cancelled 2G licences, and restriction of technological options.
Spectrum packaging	High risk	Band fragmentation and small lot sizes diminished the scope to acquire large contiguous packages.
Auction format	High risk	The format presented a significant risk of being stuck with an unwanted sub-set of a target package. Given the concerns about spectrum packaging, this introduced a heightened risk of buyer inefficiency.
Overall assessment	High risk	The reserve prices were too high given the risks introduced by the uncertain direction of regulatory policy.

Source: Coleago Consulting assessment

5.4 Australia 700MHz auction

The Australian Digital Dividend auction in 2013, which used a CCA format, included 2x45MHz at 700MHz sold on a national basis plus 2x70MHz at 2.5GHz sold on a regional basis. All spectrum was sold in blocks of 2x5MHz, with acquisition caps per bidder of 2x25MHz at 700MHz plus 2x40MHz at 2.6GHz in each of the 11 regions.

The reserve price for 700MHz was $1.25/MHs/pop (A$1.36), which was 89% more than the price of realised for 800MHz in the preceding UK auction and 73% higher than the European average at the time[39].

The auction resulted in an allocation of 2x20MHz at 700MHz for Telstra, the market leader, and of 2x10MHz in this band for SingTel Optus. VHA, the third operator, did not acquire any spectrum. Accordingly, a third the prime 700MHz band was unsold and now lies fallow. Telstra and Optus paid the reserve price for their winning packages, plus a small assignment premium. We are not in a position to determine how much of the unsold 700MHz might have been allocated if the reserve price had been lower. Nevertheless, the high 700MHz price is certain to have led to:

- **A significantly increased risk of incomplete allocation;**
- **A high risk of increased retail prices, offsetting the social gains from direct spectrum fee receipts.**

The auction design did include one positive innovation. The activity rules specified that a bid that included three or more lots of 700MHz in one clock round had to include at least two in the following round. This reduced the chance of ending the clock-phase with significant excess supply[40], which would increase uncertainty for bidders and potentially complicated bidding. In the event, this rule did not bear on the progress of the award, but the regulator deserves credit for implementing a positive measure.

39 European average: Coleago Consulting estimate based on 30 June 2013 exchange rates.

40 Significant excess supply might arise due to a single bidder dropping from a large package to a nothing, with a view to ending the clock phase prematurely. This opens a potential avenue for strategic bidding, a detailed discussion of which is beyond the scope of this report.

Our overall assessment of 700MHz component of the combined award is provided in the table below.

EXHIBIT 22: AUSTRALIA 700MHZ AUCTION SCORECARD

Policy	Risk score	Comments
Spectrum caps	Low risk	A cap of 2x20MHz would have offered a stronger safeguard against high 700MHz concentration in a three-bidder scenario. This would not exclude provisions to relax the cap when only two candidates emerged.
Reserve Price	High risk	The reserve price was 73% higher than average European prices for 800MHz. Moreover, the auction resulted in a third of the 700MHz band being unsold.
Auction rules	Positive	Modification to the activity rules to minimise the risk of strategic bidding and heightened uncertainty for bidders during the auction.
Overall assessment	High risk	The unusually high reserve prices may have contributed directly to 33% of the prime 700MHz band being left unsold.

Source: Coleago Consulting assessment

5.5 Chile AWS auction

In September 2009, Chilean regulator Subtel auctioned 2x45MHz of spectrum in the AWS band (1700MHz paired with 2100MHz), in three blocks of 2x15MHz. This represented a 53% increase in mobile industry holdings. A cap on total spectrum holdings of 2x30MHz per operator was imposed, which excluded the three incumbents (Mobistar, Entel and Claro) from the auction[41].

The cap thus represented a de facto set-aside for new entrants, leading to the award of two blocks of AWS spectrum to Nextel and one block to triple-play operator VTR. The latter closed its mobile operations in 2013, while Nextel still serves less than 0.9% of the market, over four years later[42]. Accordingly, the new market entry has had a negligible impact on the market, and this seems unlikely to change soon.

Licence conditions stipulated the launch of nationwide services within a year of the AWS spectrum award, which neither entrant was able to meet: 3G services were launched two and a half years after licencing. Stringent deployment obligations seem pointless if they are not enforced, and it will likely be difficult for the regulator to reverse the chronic underutilisation of these resources in the foreseeable future.

The AWS spectrum represents almost a quarter of the available mobile bandwidth in Chile prior to the recent 700MHz award. Significantly, as set out section 4.5.3, this outcome also delayed the introduction of LTE in the Chilean market, at an estimated cost of between $24 and $192 per capita per year in foregone GDP growth.

EXHIBIT 23: CHILE AWS AUCTION SCORECARD

Policy	Risk score	Comments
Spectrum caps	High risk	De facto spectrum reservation for new entrants lead to highly inefficient use: 23% of mobile bandwidth (prior to the 700MHz award) benefiting less than 1% of mobile customers.
Reserve Price	Neutral	The reserve price under $0.01/MHz/pop was sufficiently low to ensure a full sale to new entrants.
Overall assessment	High risk	Gross underutilisation of scarce resources, that is difficult to reverse.

Source: Coleago Consulting assessment

While the Chilean AWS auction in 2009 generated a poor outcome for consumers, policy during the 2014 award of 700MHz spectrum was more closely aligned with key public interest criteria, as set out below.

41 Source: GSMA Mobile Policy Handbook, Case study on spectrum caps.

42 Based on GSMAi data as of Q4 2013.

5.6 Chile 700MHz auction

The 2014 award in Chile represented the first allocation of 700MHz spectrum in Latin America under the APT band-plan. 2x35MHz of this spectrum was made available and was split into two blocks of 2x10MHz plus a single block of 2x15MHz.

These were secured by the three incumbents for prices ranging between $0.002/MHz/pop and $0.024MHz per pop (for the largest block). The award process was part 'beauty-contest', part sealed-bid auction.

Key evaluation criteria included coverage and service-quality commitments, which took precedence over took precedence over auction receipts. Mandated roaming provisions also applied. Promoting network investment, connecting isolated regions and schools, as well as bridging the digital divide were overt policy objectives[43].

EXHIBIT 24: CHILE 700MHZ AUCTION SCORECARD

Policy	Risk score	Comments
Spectrum packaging	Positive	The packaging of spectrum in three blocks ensured that technically efficient holdings were available while precluding high concentration of 700MHz spectrum.
Price	Positive	Prices paid were up to $0.024/MHz/pop which is low by international standards.
First price sealed-bid format	Low risk	The fee offer was only one of the evaluation criteria, and no more than three credible candidates were likely for the three available blocks. This greatly reduced the risk of misallocation to which the format is normally prone.
Overall assessment	Positive	The policy focus on coverage and service commitments rather than spectrum fee receipts reduced the overall risk of distortion. The available spectrum was sold at low prices and all operators had a fair chance to secure the resources they needed.

Source: Coleago Consulting assessment

5.7 Canada AWS auction

The 2008 AWS spectrum auction in Canada included 2x45MHz. One 2x5MHz and two 2x10MHz blocks were available to all bidders and two 2x5MHz blocks and one 2x10MHz block had been set aside for new entrants. The auction used an SMRA format on a regional basis. There were five significant new entrants (Shaw, Wind, Mobilicity, Videotron and Eastlink) who won spectrum. The rules attached to the set-aside spectrum prevented winning bidders from reselling the spectrum for a period of 5 years.

The auction outcome led to significant inefficiencies and the auction rules distorted bidding behaviour. Three out of the five new entrants either failed to roll-out or deployed a declining technology, and are in or near insolvency. In 54 out of 16 regions in Canada, all of the set-aside spectrum is used sub-optimally or not used at all.

43 According to a Subtel source quoted by BN Americas, September 2013; source: BNamericas, February 2014.

- Shaw, an existing fixed operator has not deployed 5 years after the auction. Shaw plans to resell the spectrum at a premium to a large incumbent after the five year lock up period ends in 2014.
  - During 2013, Shaw granted an option to Rogers to acquire its AWS spectrum licences for CN$350 million and received CN$50 million for granting this option. In the auction Shaw paid CN$191 million for the spectrum. Since Rogers is prepared to pay CN$350 million for spectrum which the government sold to Shaw for CN$191 million, the loss to the public purse is CN$ 159 million. This loss to the public purse will be captured by the shareholders of Shaw once the five year lock-up period ends in Q3 2014.
  - Shaw acquired between 2x5MHz and 2x15MHz in many regions, including large cities of Vancouver, Calgary, Edmonton and Winnipeg with high traffic densities. Shaw did not deploy whereas the three national operators deployed LTE in their non-set-aside AWS spectrum. Without the set-aside the spectrum acquired by Shaw would have been acquired by the three incumbents who would have added this to their LTE deployment to deliver higher headline speeds and additional capacity. Instead the set-aside spectrum lay fallow for five years.
- Mobilicity acquired between 2x5MHz and 2x10MHz blocks in different regions, including large cities such as Toronto, Vancouver and Calgary.
  - Mobilicity had insufficient spectrum to deploy LTE and HSPA and opted for HSPA, whereas other operators deployed LTE in the AWS band. This means older technology which is less spectrally efficient was deployed, thus reducing the economic benefit extracted from the spectrum.
  - In 2014 Mobilicity, having failed to gain sufficient customers, entered administration. As of the 16th of June 2014 Mobilicity's customer base amounted to a mere 157,000 out in a population of 35 million and the customer base is dwindling. Therefore the valuable AWS spectrum is under-utilised, further reducing its value to the Canadian economy.
- Wind acquired 2x5MHz and 2x10MHz blocks in 54 out of 61 regions, including all large cities with the exception of Montreal and Quebec.
  - Like Mobilicity, Wind had insufficient spectrum to deploy LTE and HSPA and opted for HSPA, older technology which is less spectrally efficient than LTE was deployed, thus also reducing the economic benefit extracted from the spectrum.
  - Wind failed to attract sufficient customers and revenue. After writing off the value of Wind Mobile entirely in March 2014, Wind's shareholder Vimpelcom is looking for an exit from the Canadian market.
- Vidéotron acquired AWS spectrum in many regions but did not deploy its network in all regions, notably in Toronto. As such, the most densely populated city in Canada was deprived from the benefit of 2x5MHz of AWS spectrum, thus reducing headline speed and capacity for at least 5 years.
- Fifth entrant Eastlink also acquired spectrum in a number of regions, but failed to deploy in each of these five years on. Thus, some of the entrants did not deploy at all, and none deployed in all the regions in which they secures AWS spectrum, leading to underutilised resources across the Canadian territory.

The auction rules distorted bidding behaviour. The new entrants who were allowed to bid for the set aside blocks were also allowed to bid for the non-set aside blocks. The SMRA format allowed them to park eligibility points by parking bids in the non-set aside spectrum and later switching to the set-aside spectrum. This means that prices paid for the set-aside spectrum were much lower than for the non-set aside spectrum. This translates into a loss to the public purse.

EXHIBIT 25: CANADA AWS AUCTION SCORECARD

Policy	Risk score	Comments
Spectrum set-aside	High risk	Loss to the public purse as spectrum was sold for less than others were prepared to pay; non-deployment and under-utilisation deprived the public of the full economic value of the spectrum.
Reserve prices	Neutral	All spectrum was sold at a premium to the reserve, hence no visible distortion.
Auction rules	Medium risk	The rules offered an opportunity for entrants to unduly drive up prices paid by incumbent operators.
Overall assessment	High risk	This is an extremely negative outcome for Canada with reduced auction receipts and gross underutilisation of scarce resources and failure of the Government's objective to create a fourth national wireless operator.

Source: Coleago Consulting assessment

5.8 Bangladesh 3G auction

A total of 2x50MHz at 2100MHz was made available during the Bangladesh 3G award in September 2013, of which 2x40MHz was auctioned directly, while 2x10MHz was reserved for state-owned operator Teletalk at the auction-determined price. The block allocated to Teletalk doews not reflect the needs of its customer base, since it has less that a 3% share of the market.

Market leader GrameenPhone secured a block of 2x10MHz during the auction, while Robi, Airtel and Banglalink each secured 2x5MHz. A block of 2x10MHz was to be allocated directly to state-owned operator Teletalk, which has less than a 3% share of the market, at the auction-determined price[44]. The net result is that three blocks of 2x5MHz blocks or 37.5% of the 2100MHz spectrum for sale was left unsold. The regulator may seek to award these blocks in a future award, however, it seems likely that a reduction in the reserve price will be necessary to achieve this, at least in the short term.

The auction followed a 'public outcry' process in two stages –the first for allocations of 2x10MHz per bidder, the second for 2x5MHz. The winners all paid the reserve price of $21 million per paired MHz. This equates to $0.07/MHz/pop, which seems especially high for a market that generates less than $2 in monthly revenues per customer.

Should the unsold spectrum remain fallow for an extended period, we estimate the impact of the lost economic opportunity in the order of $1.0 billion per year.

EXHIBIT 26: BANGLADESH 3G AUCTION SCORECARD

Policy	Risk score	Comments
Spectrum set-aside	Medium risk	Setting 2x10MHz for a state-backed operator with less than 3% market share risked an inefficient allocation of scarce resources. In the event, the risk was obviated by lack of demand due to other factors.
Reserve prices	High risk	37.5% of the available spectrum was left on the shelf. The reserve price was thus too high in light of all prevailing circumstances.
Regulatory uncertainty	High risk	Ongoing tax disputes and regulatory uncertainty may have depressed demand for the available resources.
Overall assessment	High risk	The combination of high reserves and regulatory issues contributed to vital spectrum resources remaining unsold.

Source: Coleago Consulting assessment

44 Based on GSMAi data as of Q1 2014.

6. Conclusions and recommendations

Our analysis leads us to conclude the following in particular.

1. **Explicit or de facto spectrum set-asides present a high risk of distortion and inefficiency. In an era of mobile network consolidation, diverting spectrum to new infrastructure-based entrants seems a highly questionable policy.**
2. **Governments in many countries appear to view spectrum policy as an instrument to finance the state. However, measures designed to maximise licence fee receipts risk introducing severe downstream inefficiencies that cause net social and economic harm.**
3. **The overriding focus of spectrum policy should be to promote: (a) efficient use of spectrum resources particularly where internationally harmonized; (b) network investment and innovation; (c) undistorted competition; and (d) sustainably high output and low retail prices.**

The social and economic cost of inefficient allocations is often substantial, especially if spectrum is left fallow or is underutilised for prolonged periods. Where spectrum is left unsold due to artificially high reserve prices, these costs sometimes far exceed the extra auction proceeds that may reasonably be attributed to them.

To minimise the risk of distortions, we strongly recommend that policy-makers consider the following measures in future spectrum awards:

- **Applying spectrum floors in the event spectrum-in-use is being re-auctioned, to minimise the threat to business continuity;**
- **Aligning reserve prices with the higher of (a) the costs of freeing up the spectrum for mobile use or (b) the valuations based on alternative industry uses, to avoid imposing unduly high costs on the industry (that might otherwise be passed on to consumers in the form of higher retail prices or reduced investment and innovation);**
- **Providing deferred licence fee payment terms to equalise the opportunity for operators to secure the resources they need to pay for spectrum, in light of possible differences in their ability to raise substantial funds in advance;**
- **Modifying auction rules to minimise the scope for predatory bidding strategies designed to drive higher costs for rival bidders;**
- **Imposing 'use it or lose it' provisions in the form of non-band specific coverage obligations to minimise the threat of spectrum hoarding, particularly where spectrum is awarded at a discount to entrants via a set-aside; for example, band-agnostic coverage obligations would minimise the risk that entrants secure spectrum with the aim to hold and sell at a premium;**
- **Ensuring early industry participation when preparing/deciding on spectrum award procedures and ensuring adequate transparency level for all auction participants throughout;**
- **Avoiding the use of auctions when an obvious distribution of available resources among operators can be readily identified, to minimise the risk of perverse outcomes.**

Appendix: Key assumptions used in the case studies

India case study assumptions

To calculate the impact of spectrum shortfalls on Economic Surplus, we need to estimate the total voice traffic lost as a result of congestion. Key assumptions used to obtain this result are provided below.

Busy-hour traffic profile:

- **Total quarterly voice traffic in Q4 2013: 972 billion minutes (source: GSMAi).**
- **Total traffic in the site busy hour: 10% (Coleago assumption); note that this is taken to be the sum of individual site busy hours rather than the whole network busy hour.**
- **On this basis, we calculate total voice traffic in the busy hour as 1.1 billion minutes.**
- **An equivalent 'single national network' is imagined, on which all allocated spectrum is taken to be deployed. The corresponding site count applied is the average across operators weighted by spectrum holdings. Based on GSMAi data and Coleago assumptions, the site count applied is 90,000 across the territory.**
- **Based on Coleago's experience in a variety of markets, we assume that unconstrained demand is distributed as follows across the network:**
  - **The top 1% of site carries 3% of total busy hour voice traffic;**
  - **The top 10% carry 30% of peak traffic;**
  - **The top 20% carry 50%;**
  - **The top 50% carry 80%;**
  - **The remainder carries 20% of total busy hour traffic.**
- **A rectilinear approximation of the above curve was applied in the computation.**

Maximum capacity per site:

- **As a rule of thumb, Coleago engineers assume that every 5MHz paired of 2G spectrum can carry around 1500 minutes per site in the busy hour. This allows for 15% of traffic at half-rate and 2.7 effective sectors per site. No additional site densification is assumed.**
- **With the spectrum quantities in the factual case, this yields a capacity of 20,000 minutes per hour per site on our 'equivalent single national network'.**
- **Deploying the additional spectrum in the counterfactual case increase this capacity to 26,000 minutes per hour per site.**
- **Converting busy-hour traffic foregone into total traffic foregone:**
- **Congestion levels are calculated for every hour of the day, assuming that average daily site traffic is distributed as follows:**
  - **10% of traffic is concentrated in the busy hour;**
  - **0.5% of traffic in the quiet hour;**
  - **3 busy hours per day and 5 quiet hours;**
  - **Progressive evolution of traffic intensity from busy to quiet hours, to yield 100% of total daily traffic.**
- **The sum of any traffic lost to congestion in each hour yields the daily total.**

Potential drawbacks with this methodology:
While it is undoubtedly true that congestion curtails communication, some of the traffic could shift to quieter hours. This is taken to be a second-order effect however, as we do not usually observe wider traffic distributions in congested parts of the network than in uncongested parts. Since the general shapes of the demand profiles seem to hold true, we can use these to gauge the extra demand that would in fact appear with the provision of additional capacity.

Calculating Producer Surplus:
The unmet demand is valued at the prevailing prices. Our estimate of the incremental costs that would be incurred by operators to serve the extra traffic is based on the following assumptions:

- **Six additional transceivers (TRX) are required to deploy an additional 5MHz paired per site, at an average cost of $1,500 per unit, allowing for installation and additional equipment.**
- **We assume that the additional spectrum would be deployed on 30% of sites (this is slightly more than the percentage of sites that are actually congested).**
- **Interconnect expenses are ignored on the basis that these are broadly neutral across the whole industry.**
- **Additional transmission costs are assumed to be a second-order effect and are also ignored.**
- **This yields net incremental costs of around 17% of incremental revenues.**

Bangladesh case study assumptions
The same parameters are applied for 3G voice as in the India case study. Additional assumptions include the following:

- **For 3G voice traffic, we take an equivalent 3G voice data rate of 12kbps.**
- **For 3G data, we assume an effective capacity of 6.7Mbps per 5MHz paired per site.**

Total voice traffic in the Bangladesh market and operator site counts (where available) were sourced from GSMAi. All other assumptions are our own.

Floor 2,
The Walbrook Building
25 Walbrook,
London EC4N 8AF UK
Tel: +44 (0)207 356 0600

spectrum@gsma.com
www.gsma.com